

# Flour Characteristics Related to Optimum Water Absorption of Noodle Dough for Making White Salted Noodles

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ABSTRACT

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Physicochemical properties of 34 wheat flours with various classes and different protein contents were related to optimum water absorption of noodle dough. Club and soft wheat flours generally exhibited higher water absorption (34–37%) of noodle dough than hard wheat flours (31–35%). Optimum water absorption of noodle dough in three hard wheat flours with five different protein contents was 33–37%. Optimum water absorption was negatively correlated with flour protein content and SDS sedimentation

volume. Physical properties of flour, damaged starch content, NIRS hardness and water retention capacity, influenced optimum water absorption of noodle dough from club, soft and hard wheat flours. A prediction equation developed using protein content, water retention capacity and SDS sedimentation volume of flour provides a reliable estimation of the optimum absorption of noodle dough for making noodles.

Noodles are popularly consumed in many Asian countries because of their simple preparation process, low price, and easy, fast cooking. There are regional preferences for color, size, shape, texture, and flavor of noodles, which depend not only on flour characteristics, but also on the specific process used to manufacture the noodles, as well as the inclusion of other raw materials or chemical additives (Dick and Matsuo 1988). Texture and color are generally considered as the most important quality parameters of noodles, albeit there are wide ranges of Asian noodles, and each type of noodle has its unique quality requirements. White salted noodles are generally prepared from wheat flour, water, and salt through mixing, sheeting, and cutting processes. Although flour characteristics required for baking bread are similarly important for making noodles, the influence of flour properties on noodles is greater than in breadmaking because of the simple formula and processing of white salted noodles (Nagao 1992).

Both starch (Nagao et al 1977; Oda et al 1980; Toyokawa et al 1989; Crosbie 1991) and protein (Oh et al 1985b) mainly govern the textural properties of noodles. Starch characteristics, including amylose-amylopectin ratio, starch pasting properties, and swelling powers (Toyokawa et al 1989; Crosbie 1991; Crosbie et al 1992; Konik et al 1992) are highly related to eating quality of white salted noodles. Oh et al (1985b), Huang and Morrison (1988), Konik et al (1992), and Baik et al (1994) emphasized the role of protein content and quality, as measured by SDS sedimentation test, mixograph, and alveograph, on texture of noodles. In addition to flour constituents, processing conditions such as water absorption, mixing, and sheeting also have large influences on quality of noodles.

Dough mixed with an excessive amount of water exhibits poor sheeting properties when dough is passed through rolls, while insufficient water absorption tends to produce stiff and less extensible noodle sheets. Oh et al (1985a) reported that water absorption of noodle dough affected noodle color, wet strength, and dry strength of noodles. Sheeting, cutting, and drying of noodles became difficult when water absorption deviated >2–3% from optimum. Oh et al (1986) and Seib et al (2000) proposed a method for determining optimum water absorption for making noodles using a mixograph or farinograph. Mixograph or farinograph absorption of flour is largely influenced by and positively related to protein content and quality. Because a limited amount of water is used for making noodles compared with the amount of water used for baking bread, there is minimum development of gluten during mixing of noodle dough. Kruger (1996) reported that the farinograph could be a rough guide

for the water absorption of noodle dough. The practical use of a 10-g mixograph to predict water absorption for making noodles has been scarce due to its inconvenience (Hou 2001). Therefore, instrumentations and methodologies used for the determination of water absorption for baking bread may not be suitable for estimating water absorption for making noodles.

At present, no objective methods or instrumentations are available to determine optimum absorption for making noodles. Instead, optimum water absorption for making noodles has been determined by experienced personnel based on handling properties of noodle dough in industries, or a fixed absorption for making noodle dough has been applied in laboratories for the evaluation of noodle making quality of wheat flours. The objectives of this study were to determine flour characteristics affecting water absorption for making noodles and to develop a prediction model for determination of the optimum water absorption for making white salted noodles.

## MATERIALS AND METHODS

### Materials

Sixteen wheat flours, including three club, three soft white spring (SWS), three soft white winter (SWW), four hard white (HW), and three hard red spring (HRS) wheat, were obtained from the Western Wheat Quality Laboratory (Pullman, WA). Wheat grains with five different protein contents of three HW wheat cultivars, ID377S, ML455, and Nuwest, were provided by Pro-Mar Select (Spokane, WA). Wheat was milled to ≈60% extraction on a Bühler experimental mill. Two commercial wheat flours, Com1 and Com2, suitable for making udon noodles were obtained from Nissin Flour Milling (Tokyo, Japan). One commercial wheat flour for making Korean dry noodles (Com3) was provided by W. J. Park, U.S. Wheat Associates in Seoul, South Korea, through the Wheat Marketing Center (Portland, OR).

### Analytical Methods

Moisture, protein, and ash content of wheat flour were determined according to Approved Methods 44-15A, 46-30, and 08-01 (AACC 2000). The determination of damaged starch content followed the procedure described by Gibson et al (1992), using an enzymatic assay kit (MegaZyme Pty., Ltd., North Rocks, Australia). NIRS hardness of flours was determined (400 InfraAlyzer, Technicon, Tarrytown, NY). Particle size distribution of flour was determined using a sonic sifter (model L3, ATM Corp, Milwaukee, WI) equipped with sieves with openings of 38 and 106  $\mu\text{m}$ . SDS sedimentation test was performed according to the procedure of Axford et al (1979) with a modification to 3 g of flour weight. Total pentosan content was determined according to the procedure of Hashimoto et al (1987). Water retention capacity was determined according to the procedure of Kitterman and Rubenthaler (1971) using water instead of sodium bicarbonate.

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## Noodle Making

Noodle making was conducted in two experiments. Experiment I was conducted to determine the effects of water absorption on processing properties of dough and quality parameters of noodles. Experiment II was performed to determine optimum and minimum water absorption of noodle dough in flours of various wheat classes and protein contents. In Experiment I, three wheat flours, including HRS wheat cultivar WPB926 and SWW wheat cultivars Stephens and Com1, were prepared into white salted noodles with absorption ranges of 31–39%.

Flour (100 g, 14% mb) was mixed with sodium chloride solution (31–39 mL) in a pin mixer (Swanson-Working, National Mfg., TMCO Division, Lincoln, NE) for 4 min with a head speed of 86 rpm. The concentration of sodium chloride solution for making noodles with different absorptions was adjusted to contain 2.0% sodium chloride in noodle dough. Dough was passed through the rolls of a noodle machine (Ohtake Noodle Machine, Tokyo, Japan) at 8 rpm and a 3-mm gap; dough was folded and put through the sheeting rolls. The folding and sheeting were repeated twice more. The dough sheet was rested for 1 hr and then put through the sheeting rolls three times at progressively decreasing roll gaps of 2.60, 2.33, and 2.00 mm. Immediately after the last sheeting, thickness of the dough sheet was measured (Peacock Dial Thickness Gauge G, Ozaki Mfg., Ozaki, Japan). A piece of noodle sheet was placed in plastic bags for determination of color. The rest of the dough sheet was cut through no. 12 cutting rolls into strips ≈30 cm in length. The color of the dough sheet was measured by colorimeter (CM-2002, Minolta Camera, Osaka, Japan) with an 11-mm measurement aperture. The color differences of noodle sheets were recorded as CIE-LAB  $L^*$  (lightness),  $a^*$  (redness-greenness), and  $b^*$  (yellowness-blueness) values.

Raw noodles (20 g) were cooked for 18 min in 500 mL of boiling distilled water and then rinsed with cold water. Two replicates of

cooked noodles were evaluated by texture profile analysis (TPA) using a texture analyzer (TA-XT2, Stable Micro Systems, Haslemere, England) within 5 min after cooking. A set of five strands of cooked noodles was placed parallel on a flat metal plate and compressed crosswise twice to 70% of their original height using a 1.5-mm metal blade at a speed of 1.0 mm/sec. From force-time curves of the TPA, the hardness, springiness, and cohesiveness were determined according to the description of Baik et al (1994).

In Experiment II, white salted noodles were prepared with 16 wheat flours from various classes of wheat and three HW wheat flours with different protein contents with optimum and minimum absorption. The optimum water absorption of noodle dough for making white salted noodles was determined based on appearance, and sheeting and handling properties of dough during the noodle making process by experienced personnel through trial and error. Commercial wheat flour, which required 35% absorption to make uniform, smooth, and nonsticky dough, was used as a reference to be compared with other flours during the determination of optimum water absorption for making noodles. The minimum water absorption of noodle dough was the least amount of water required for flour to make a continuous piece of noodle dough sheet after three foldings and sheetings through rolls with a 3-mm gap. The minimum water absorption of noodle dough could be determined more objectively than optimum water absorption of various flours for making noodles, because the minimum water absorption was determined based on whether a continuous dough sheet was formed during the sheeting process, while the determination of optimum water absorption required more subjective evaluation, as described previously. The noodle dough sheet prepared with minimum water absorption was dry and felt stiff compared with the dough sheet with optimum water absorption. Noodle sheets were prepared and tested as described in Experiment I.

**TABLE I**  
Flour Characteristics of Club, Soft White Spring (SWS), Soft White Winter (SWW), Hard White (HW), Hard Red Spring (HRS) Wheat, and Commercial Flours for Making Noodles<sup>a</sup>

Class and Cultivar	Protein (%)	Ash (%)	SDSS <sup>b</sup> (mL)	TPC <sup>c</sup> (%)	WRC <sup>d</sup> (%)	Damaged Starch (%)	NIRS Hardness	Particle Size of Flour (%)		
								>106 μm	38–106 μm	<38 μm
Club										
Calorwa	11.4	0.49	39.0	1.25	58.1	2.7	27.6	16.5	55.8	27.7
Bruehl	8.9	0.55	25.5	1.18	55.3	3.1	30.8	17.7	58.6	23.7
Hiller	8.2	0.55	18.5	1.21	54.4	2.8	34.1	16.4	59.1	24.6
SWS										
Treasure	10.3	0.53	33.5	1.15	54.1	3.1	35.0	18.0	60.0	22.0
Vanna	11.7	0.54	49.5	1.19	54.4	2.7	28.1	15.5	56.7	27.8
Alpowa	8.9	0.43	40.0	1.22	50.6	2.0	28.7	20.0	54.6	25.4
SWW										
Stephens	12.2	0.48	43.0	1.23	58.4	3.6	45.6	21.6	63.1	15.2
Madsen	10.9	0.53	31.0	1.20	57.9	3.6	45.1	20.3	63.1	16.6
OR939526	11.9	0.49	42.0	1.34	60.3	3.4	47.2	21.1	62.8	16.1
HW										
Winsome	14.3	0.50	51.5	1.21	69.7	6.0	80.2	24.0	70.4	5.6
Nuwest	10.9	0.54	41.0	1.16	64.5	5.7	78.4	21.1	76.0	2.9
Klasic	14.9	0.46	57.0	1.21	65.1	4.6	56.0	17.6	69.9	12.5
IDO377S	13.6	0.51	45.5	1.21	61.7	4.8	86.7	29.8	65.5	4.8
HRS										
WA7839	16.9	0.51	75.0	1.22	66.3	4.2	69.1	20.2	72.0	7.8
WPB926	17.5	0.55	79.5	1.34	68.2	3.9	71.5	21.9	69.2	8.9
Butte86	16.2	0.45	–	1.32	63.2	4.8	101.7	32.1	65.0	2.9
Commercial <sup>e</sup>										
Com1	10.1	0.36	29.0	1.12	53.9	3.1	33.4	12.5	65.2	22.3
Com2	10.2	0.37	30.0	1.28	67.2	6.9	38.8	8.0	68.2	23.8
Com3	10.8	0.42	36.5	1.24	65.3	6.6	34.6	8.3	71.3	20.5
LSD <sup>f</sup>	0.04	0.05	2.77	0.19	0.54	0.52	1.50	0.18	0.58	0.63

<sup>a</sup> Results expressed on a dry weight basis.

<sup>b</sup> SDS sedimentation volume.

<sup>c</sup> Total pentosan.

<sup>d</sup> Water retention capacity.

<sup>e</sup> Com1 and 2 = commercial noodle flours from Japan; Com3 = commercial noodle flour from Korea.

<sup>f</sup> Least significant difference ( $P = 0.05$ ). Differences between two means exceeding this value are significant.

## Statistical Analysis

Statistical analysis of data was performed using SAS software (SAS Institute, Cary, NC) with Fisher's least significant difference (LSD), analysis of variance (ANOVA), Pearson's correlation coefficient, and *F*-test of multiple regressions. Differences were considered significant at *P* < 0.05, unless otherwise specified. All data were determined at least in duplicate and all were averaged.

## RESULTS AND DISCUSSION

### Characteristics of Flour

Characteristics of 16 wheat flours of various classes of wheat, including three club wheats, three SWS wheats, three SWW, four HW wheats, and three HRS wheats are summarized in Table I. Protein content of flours was 8.2–12.2% in club, SWS, and SWW wheat cultivars, and >13.6% in HW and HRS wheats, except in Nuwest (10.9%). Protein content of commercial noodle flours was 10.1–10.8%. Ash content of club, SWS, SWW, HW, and HRS wheat flours was 0.43–0.55%, whereas ash content of commercial noodle flours was <0.42%. SDS sedimentation volume of flours was 18.5–39.0 mL in club, 31.0–49.5 mL in SWS and SWW, and 41.0–79.5 mL in HW and HRS wheats. Commercial flours for

making noodles exhibited SDS sedimentation volumes of 29.0–36.5 mL. Generally, higher SDS sedimentation volumes in HW and HRS wheats than in club, SWS and SWW wheats were due to high protein content or high proportion of high molecular weight proteins. Protein content was highly correlated with SDS sedimentation volume (*r* = 0.928, *P* < 0.001). Total pentosan content of wheat flours was 1.12–1.34% and was not significantly different among 16 wheat flours and three commercial flours. HW and HRS wheat flours showed higher water retention capacity (61.7% for IDO377S to 69.7% for Winsome) than club, SWS, and SWW wheats. Water retention capacity was <60.3% in club, SWS, and SWW wheat cultivars. Water retention capacity of Com1 was similar to that of soft wheat cultivars, while Com2 and 3 had much higher water retention capacity than Com1, similar to HW and HRS wheat flours. Damaged starch content was >3.9% in HW and HRS wheat flours but <3.6% in club, SWS, and SWW wheats. Com1 had 3.1% damaged starch, similar to SWS and SWW wheats, while Com2 and Com3 had >6.6% damaged starch, higher than SWS, SWW, HW, and HRS wheats. The high proportion of damaged starch in Com2 and 3 probably contributed to their high water retention capacity. NIRS hardness score was <35.0 in club and SWS wheats, 45.1–47.2 in SWW wheat, and >56.0 in HW

TABLE II  
Flour Characteristics of Three Hard White Spring Wheat Cultivars with Different Protein Content<sup>a</sup>

Cultivar	Protein (%)	Ash (%)	SDSS <sup>b</sup> (mL)	TP <sup>c</sup> (%)	WRC <sup>d</sup> (%)	Damaged Starch (%)	NIRS Hardness	Particle Size of Flour (%)		
								>106 μm	38–106 μm	<38 μm
IDO377S	11.0d	0.61ab	45.0e	1.30a	71.7a	7.8a	67.1c	12.4b	81.7a	5.9b
	11.8cd	0.60b	50.0d	1.24ab	71.2ab	7.7a	67.2bc	12.1c	80.7b	7.3a
	12.7c	0.61ab	53.5c	1.14b	71.4ab	7.2ab	66.7c	11.8d	80.8b	7.5a
	13.6b	0.63a	55.5b	1.22ab	70.4b	6.7bc	68.8b	12.6a	80.3b	7.0a
	14.9a	0.61b	62.0a	1.18b	68.5c	6.4c	70.7a	12.4b	80.9b	6.7a
ML455	9.4e	0.50d	47.0d	1.19a	76.9a	8.7ab	65.9a	9.5c	77.4b	13.2b
	11.2d	0.56c	58.7c	1.31a	74.4b	9.1a	64.5ab	9.3c	76.8b	14.0a
	12.8c	0.55c	66.7c	1.34a	72.6c	8.1b	65.6a	10.7a	79.1a	10.2c
	13.1b	0.59b	70.0b	1.34a	70.5d	7.3c	63.4b	10.2b	79.3a	10.5c
	15.3a	0.62a	78.2a	1.24a	74.3b	7.5c	65.8a	10.7a	79.5a	9.8c
Nuwest	11.6e	0.46a	58.0e	1.23a	66.0e	7.5a	–	11.2ab	79.3e	9.5a
	12.4d	0.40d	63.5d	1.16a	71.9b	7.5a	49.0c	11.2a	81.0d	7.8b
	12.7c	0.42bc	65.0c	1.16a	67.3d	7.3ab	61.6a	11.1ab	82.9a	6.0d
	14.0b	0.43b	68.0b	1.14a	75.3a	7.9a	58.7b	10.8b	82.2b	7.0c
	14.3a	0.42c	70.5a	1.21a	70.1c	6.5b	58.6b	10.9ab	81.8c	7.3c

<sup>a</sup> Results expressed on a dry weight basis. Values followed by the same letter are not significantly different (*P* < 0.05).

<sup>b</sup> SDS sedimentation volume.

<sup>c</sup> Total pentosan.

<sup>d</sup> Water retention capacity.

TABLE III  
Effect of Water Absorption on Characteristics of Noodle Sheet and Texture Parameters of Cooked Noodles<sup>a</sup>

Flour	Noodle Sheet						Cooked Noodle		
	Absorption (%)	Thickness (mm)	CIE-Lab <sup>b</sup>			Hardness (N)	Springiness (ratio)	Cohesiveness (Ratio)	
			<i>L</i> *	<i>a</i> *	<i>b</i> *				
Com1 <sup>c</sup>	39	1.6e	82.4b	–0.3c	17.4b	3.12e	0.92a	0.67a	
	37	1.6d	81.1c	–0.3c	18.4a	3.44d	0.93a	0.66a	
	35	1.7c	81.2c	–0.3c	18.2a	3.69c	0.92a	0.67a	
	33	1.7b	81.1c	–0.2b	18.1a	3.92b	0.93a	0.66a	
	31	1.8a	84.0a	0.1a	16.7c	4.04a	0.91a	0.66a	
Stephens	39	1.6d	82.0a	0.5d	19.7d	2.92e	0.92a	0.64ab	
	37	1.6d	79.2c	0.5d	21.9c	3.71d	0.93a	0.64a	
	35	1.7c	78.7d	0.7c	22.2b	4.14c	0.92a	0.64ab	
	33	1.7b	78.8d	0.8b	22.6a	4.33b	0.93a	0.65a	
	31	1.8a	79.9b	0.9a	22.3b	4.90a	0.92a	0.63a	
WPB926	39	2.1a	78.1a	1.3e	17.4c	3.66e	0.88cd	0.64a	
	37	2.0ab	76.4b	1.4d	18.5b	4.44d	0.86d	0.63ab	
	35	2.0bc	74.0d	1.5c	19.1a	5.20c	0.92a	0.64a	
	33	2.0bc	74.4d	1.6b	18.7ab	5.92b	0.90bc	0.62bc	
	31	1.9c	75.3c	1.7a	18.6ab	6.60a	0.92ab	0.61c	

<sup>a</sup> Values followed by same letters are not significantly different at *P* < 0.05.

<sup>b</sup> *L*\* = lightness; *a*\* = redness-greenness; *b*\* = yellowness-blueness.

<sup>c</sup> Com1 = commercial noodle flours from Japan.

and HRS wheats. NIRS hardness of commercial noodle flours was in the range of SWS and SWW wheats. There were distinctive differences in flour particle size distributions among wheat classes. Proportion of particles <38 µm was 22.0–27.8% in club and SWS wheats, 15.2–16.6% in SWW wheat, and <12.5% in HW and HRS wheats. Proportion of particles <38 µm of commercial noodle flours was similar to club and SWS wheats (20.5–23.8%).

The flour characteristics of three HW wheat cultivars with different protein contents are summarized in Table II. Ash content of flour increased from 0.50 to 0.62% in ML455, as flour protein content increased from 9.4 to 15.3%. However, no difference in ash content of flour with different protein content was observed in IDO377S and Nuwest. SDS sedimentation volume significantly increased as protein content increased. SDS sedimentation volume of flours with different protein contents was 45.0–62.0 mL in IDO377S, 47.0–78.2 mL in ML455, and 58.0–70.5 mL in Nuwest. There were no consistent changes in total pentosan content, water retention capacity, damaged starch, NIRS hardness, or particle size distribution of flour as protein content of flours increased. Damaged starch content of flours with various protein content was 6.4–7.8% for IDO377S, 7.3–9.1% for ML455, and 6.5–7.9% for Nuwest. Water retention capacity, damaged starch content, NIRS hardness, and particle size distribution of flour in three HW wheat cultivars were comparable to those of hard wheat cultivars previously described (Table I).

### Effect of Water Absorption on Noodles

Three different wheat flours, including commercial noodle flour, a soft white flour, and a hard wheat flour, were selected to determine the effects of water absorption on physical properties of dough sheet and texture of cooked noodles. Characteristics of noodle sheets and texture of noodles prepared with various water absorptions of noodle dough are summarized in Table III. Water absorption of noodle dough exhibited significant influences on both characteristics of noodle sheets and cooked noodles. As water absorption

increased, thinner noodle dough sheets were produced in Com1 and SWW wheat Stephens. In HRS wheat WPB926, however, noodle sheets became thicker as water absorption increased from 31 to 39%, which is in contrast to what was observed in Com1 and Stephens. Protein content of Com1 and Stephens was 10.1 and 12.2% respectively, while protein content of WPB926 was 17.5%. Difference in protein content and property of protein of flour could influence thickness of the noodle sheet at various water absorption of noodle dough. Gluten development was promoted more in WPB926 than in Com1 or Stephens during noodle dough mixing with increased water absorption. The developed gluten gave increased elastic properties to the noodle dough, which led to increased thickness of noodle dough after sheeting.

Water absorption of noodle dough exhibited no consistent effects on  $L^*$  and  $b^*$  of noodle sheets. There was, however, a consistent increase in  $a^*$  of noodle sheets as water absorption decreased in all three flours. Hardness of cooked noodles was significantly influenced by water absorption of noodle dough. In all three flours, harder noodles were produced as water absorption decreased. In Com1 and Stephens, there was a positive relationship between thickness of noodle sheet and hardness of cooked noodles. On the other hand, noodles prepared from WPB926 with lower water absorption were thinner and harder than those prepared with high water absorption. Neither springiness nor cohesiveness of noodles was affected by changes in water absorption of noodle dough.

### Optimum Water Absorption of Flours for Making Noodles

Table IV shows the thickness and color of noodle sheets of 16 wheat flours of various classes of wheat and three commercial flours. Noodle sheets were prepared with optimum and minimum water absorption of noodle dough. Noodle sheets with optimum water absorption exhibited good appearance and handling properties when dough was passed through rolls, while minimum water absorption produced stiff dough. Optimum water absorption of noodle dough

TABLE IV  
Characteristics of Noodle Dough Sheets Prepared from Club, Soft White Spring (SWS), Soft White Winter (SWW), Hard White (HW), Hard Red Spring (HRS) Wheat, and Commercial Flours for Noodles with Optimum and Minimum Water Absorption

Class and Cultivar	Optimum Water Absorption					Minimum Water Absorption				
	Absorption (%)	Thickness (mm)	CIE-Lab <sup>a</sup>			Absorption (%)	Thickness (mm)	CIE-Lab		
			$L^*$	$a^*$	$b^*$			$L^*$	$a^*$	$b^*$
Club										
Calorwa	35	1.7	78.6	0.7	19.1	29	1.8	83.7	0.9	15.4
Bruehl	37	1.6	81.4	0.3	19.5	32	1.8	85.1	0.5	15.4
Hiller	37	1.6	81.0	0.2	18.6	31	1.7	83.7	0.6	16.5
SWS										
Treasure	35	1.7	79.9	0.7	18.0	29	1.8	86.2	0.8	12.9
Vanna	34	1.7	78.9	0.8	21.2	28	1.8	83.3	1.0	16.3
Alpowa	36	1.7	81.3	0.3	16.5	32	1.7	83.5	0.6	15.3
SWW										
Stephens	34	1.7	78.5	0.8	21.8	28	1.9	84.5	0.9	16.8
Madsen	35	1.7	79.4	0.8	18.0	30	1.9	86.7	0.9	11.2
OR939526	35	1.7	77.7	1.0	22.9	29	1.9	82.3	1.3	19.2
HW										
Winsome	34	1.9	78.5	0.9	17.0	28	2.0	82.2	1.1	14.9
Nuwest	35	1.7	79.4	0.1	21.7	29	1.9	84.2	0.6	17.7
Klasic	31	2.0	81.6	0.7	15.3	25	2.3	86.7	0.7	11.7
IDO377S	33	1.8	79.5	0.6	18.2	28	2.0	83.9	0.9	15.1
HRS										
WA7839	32	1.9	75.1	1.5	19.6	26	2.0	79.9	1.5	17.1
WPB926	32	1.9	76.2	1.2	18.0	26	2.1	82.6	1.4	14.0
Butte86	32	1.9	76.2	1.2	18.0	26	2.0	82.8	1.3	13.7
Com <sup>b</sup>										
Com1	35	1.7	82.0	-0.1	18.5	28	2.0	87.2	0.5	15.6
Com2	35	1.7	81.4	-0.3	18.3	28	1.9	85.3	0.2	16.3
Com3	35	1.7	81.2	0.3	17.8	28	1.9	87.2	0.5	13.1
LSD <sup>c</sup>	...	0.02	0.59	0.12	0.69	...	0.02	0.90	0.27	0.99

<sup>a</sup>  $L^*$  = lightness;  $a^*$  = redness-greenness;  $b^*$  = yellowness-blueness.

<sup>b</sup> Com1 and 2 = commercial noodle flours from Japan; Com3 = commercial noodle flours from Korea.

<sup>c</sup> Least significant difference ( $P = 0.05$ ). Differences between two means exceeding this value are significant.

was 34–37% in club, SWS, and SWW wheat flours. Optimum water absorption was <34% in HW and HRS wheat flours, except in Nuwest, which had lower protein content and SDS sedimentation volume (10.9% and 41.0 mL, respectively) compared with other hard wheat flours. In three HW wheat flours with different protein contents, optimum water absorption of noodle dough decreased as protein content increased. Optimum water absorption was 33–37% in IDO377S, 33–37% in ML455, and 34–36% in Nuwest. The minimum water absorption of noodle dough exhibited a trend similar to that of optimum water absorption. There was significant relationship between optimum and minimum water absorption of noodle dough ( $r = 0.947$ ,  $P < 0.01$ ). As protein content and SDS sedimentation volume increased, water absorption of noodle dough decreased. Flours with low protein content and low SDS sedimentation volume required more water for generating a uniform protein matrix and making a suitable noodle sheet.

Thickness of noodle sheets prepared from optimum water absorption was 1.6–1.7 mm in club, SWS, and SWW wheat flours. Thickness of noodle sheets with optimum water absorption was >1.8 mm in HW and HRS wheat flours, except in Nuwest. Compared with commercial flours, club, SWS, and SWW wheat flours produced noodle sheets with similar thickness. Noodle sheets prepared with minimum water absorption were thicker than those with optimum water absorption. Thickness of noodle sheet was always higher with minimum absorption than with optimum absorption in HW wheat flours with different protein contents. Thickness of noodle sheets generally increased as water absorption decreased, even though each batch of noodle dough was passed through rolls

with the same gap for the same number of times to prepare noodle sheets. Thickness of noodle sheets from optimum water absorption exhibited a negative relationship with optimum water absorption of noodle dough ( $r = -0.569$ ,  $P < 0.001$ ) but was positively correlated ( $r = 0.818$ ,  $P < 0.001$ ) with protein content of flour. Kruger et al (1994) reported that the thickness of Cantonese noodle sheets was highly correlated with protein content of flour.

Color of noodles is mainly controlled by characteristics of wheat flour and to a lesser degree by processing parameters. Oh et al (1985b) proposed that a tight noodle structure resulting from a strong adherence between starch and protein would cause noodle sheets to appear translucent, resulting in less reflected light in high-protein noodles. In 16 wheat flours of various classes of wheat,  $L^*$  value of noodle sheets prepared with optimum water absorption was 77.7–81.6 in club, SWS, SWW, and HW wheat flours and <76.2 in HRS wheat flours (Table IV). HRS wheat flours produced higher  $a^*$  values of noodle sheets than other wheat flours with optimum water absorption. In commercial wheat flours,  $L^*$  value of noodle sheets was >81.2 at optimum water absorption of noodle dough. Noodle sheets prepared from commercial noodle flours exhibited the lowest  $a^*$  values, ranging from -0.3 to 0.3 at optimum water absorption. In three HW wheats with different protein contents,  $L^*$  value of noodle sheets with optimum water absorption was 78.8–79.9 in IDO377S, 78.4–80.1 in ML455, and 78.9–80.6 in Nuwest (Table V). The  $a^*$  value of noodle sheets prepared from IDO377S and ML455 increased as protein content increased with both optimum and minimum water absorption, while no difference in  $a^*$  values of noodle sheets were found among

**TABLE V**  
Characteristics of Noodle Dough Sheets Prepared from Three Hard White Spring Wheat Flours with Different Protein Contents with Optimum and Minimum Absorption<sup>a</sup>

Cultivar and Protein Content	Optimum Water Absorption					Minimum Water Absorption				
	Absorption (%)	Thickness (mm)	CIE-Lab <sup>b</sup>			Absorption (%)	Thickness (mm)	CIE-Lab		
			$L^*$	$a^*$	$b^*$			$L^*$	$a^*$	$b^*$
IDO377S										
11.00	37	1.8c	79.7b	0.4c	17.6c	31	1.9d	83.3a	0.7b	15.1ab
11.80	36	1.8bc	79.5b	0.4c	18.6ab	30	2.0c	84.0a	0.7b	15.1ab
12.70	35	1.9b	79.9a	0.6b	18.4b	29	2.0bc	83.9a	0.7b	15.2ab
13.60	34	1.9a	79.0c	0.6ab	19.1a	28	2.0b	83.4a	0.8a	16.0a
14.90	33	1.9a	78.8d	0.7a	18.6b	27	2.1a	83.7a	0.8a	14.6b
ML455										
9.40	37	1.7d	80.1a	-0.1d	15.4c	31	1.8c	83.8a	0.3d	14.0bc
11.20	36	1.8c	79.8ab	0.0d	15.4c	30	1.9b	83.3a	0.3d	13.9c
12.80	36	1.8c	78.4b	0.4c	16.8bc	31	1.9b	81.2b	0.7c	15.7ab
13.10	35	1.9b	79.0ab	0.7b	18.7a	31	2.0b	81.6b	0.8b	17.3a
15.30	33	2.0a	79.9ab	0.9a	18.1ab	28	2.1a	84.1a	1.0a	15.4bc
Nuwest										
11.60	36	1.8b	80.6a	0.3bc	17.1b	30	1.9c	85.9a	0.5bc	12.6b
12.40	36	1.8a	78.9b	0.5ab	19.3a	30	2.0b	84.9a	0.7a	15.2a
12.70	35	1.8b	79.9ab	0.1c	17.2b	29	2.0b	85.5a	0.4c	13.0b
14.30	34	1.8a	80.4a	0.6a	18.7a	28	2.1a	85.1a	0.7ab	15.1a

<sup>a</sup> Values followed by the same letter are not significantly different ( $P < 0.05$ ).

<sup>b</sup>  $L^*$  = lightness;  $a^*$  = redness-greenness;  $b^*$  = yellowness-blueness.

**TABLE VI**  
Correlation Coefficients Between Optimum Water Absorption of Noodle Dough and Flour Characteristics<sup>a</sup>

Parameters	All Flours (n = 33)	Including Commercial Flours (n = 19)	All Classes (n = 16)	Hard Wheat (n = 7)	Club and Soft Wheat (n = 9)	Three HW Wheats with Different Protein Contents (n = 14)
Protein	-0.844***	-0.928***	-0.930***	-0.780*	-0.924***	-0.939***
Ash	0.028	0.032	0.303	0.504	0.222	-0.240
Damaged starch	0.212	-0.290	-0.519*	0.785*	-0.364	0.736**
NIRS hardness	-0.415*	-0.657**	-0.643**	0.318	-0.314	-0.187
Flour particle size (<38 μm)	0.323	0.642**	0.627**	-0.703	0.280	0.306
SDS-sedimentation	0.514**	-0.862***	-0.804***	-0.662	-0.835**	-0.652*
Pentosan	0.065	-0.333	-0.343	-0.538	-0.159	0.256
Water retention capacity	-0.033	-0.600*	-0.707**	0.081	-0.399	0.274

<sup>a</sup> \*, \*\*, and \*\*\* = significant at  $P < 0.05$ , 0.01, and 0.001, respectively.

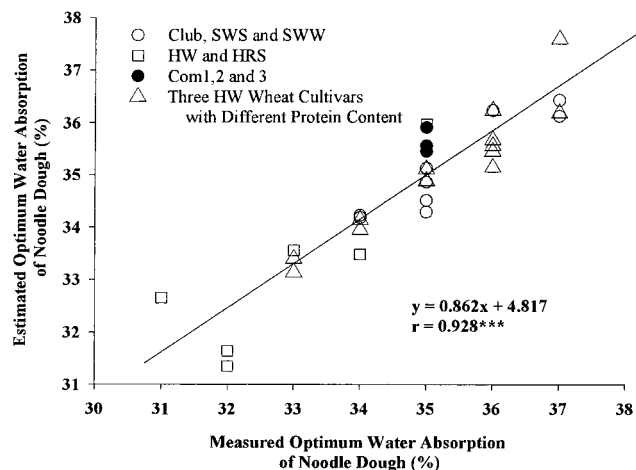


Fig. 1. Relationships between measured and estimated optimum dough water absorption of noodle dough.

flours of different protein contents in Nuwest. There was no difference in  $b^*$  value of noodle sheets with optimum water absorption in either 16 wheat flours with various classes of wheat or three HW with different protein contents. Noodle sheets with minimum absorption exhibited higher  $L^*$  and  $a^*$  values and lower  $b^*$  values than those with optimum water absorption.

There was a positive relationship between optimum water absorption of noodle dough and  $L^*$  values of noodle sheets ( $r = 0.463$ ,  $P < 0.05$ ) in all flours, including 16 wheat flours from various classes, three HW with different protein contents, and commercial noodle flours. Optimum water absorption of noodle dough exhibited a negative relationship with  $a^*$  value of noodle sheets ( $r = -0.691$ ,  $P < 0.001$ ) in all flours. Optimum water absorption correlated significantly with  $b^*$  value of noodle sheets ( $r = 0.795$ ,  $P < 0.001$ ) in three HW wheat cultivars with different protein contents. Hatcher et al (1999) and Morris et al (2000) reported that  $L^*$  value of noodle sheets generally decreased with an increase in water absorption, but  $b^*$  value increased with increasing water absorption in Cantonese noodles. Protein content of flours correlated negatively with  $L^*$  value ( $r = -0.677$ ,  $P < 0.001$ ) and positively with  $a^*$  value of noodle sheets prepared with optimum absorption ( $r = 0.733$ ,  $P < 0.001$ ) in all flours. Protein content correlated with  $b^*$  values of noodle sheets ( $r = 0.639$ ,  $P < 0.05$ ) in three HW wheat cultivars with different protein contents. Miskelly (1984), Baik et al (1995), and Yun et al (1996) also reported significant relationships between protein content of flour and color characteristics of noodle sheets.

#### Relationships Between Optimum Water Absorption of Noodle Dough and Flour Characteristics

Table VI shows the correlation between flour characteristics and optimum water absorption of noodle dough. Optimum water absorption of noodle dough was negatively correlated with protein content in all flours ( $r = -0.844$ ,  $P < 0.001$ ). Oh et al (1986) reported a negative relationship between protein content and optimum water absorption of noodle dough as determined by the mixograph. Ash content of flour was not related to water absorption for making noodles. Damaged starch content correlated positively with optimum water absorption in HW and HRS wheat flours, but not in club, SWS, and SWW wheat flours, probably due to similar damaged starch content. Optimum water absorption correlated negatively with NIRS hardness and positively with distribution of flour particle size ( $<38 \mu\text{m}$ ) in 16 wheat flours from various classes, but not in each class of wheat flour, nor in HW wheat flours with different protein contents. SDS sedimentation volume also showed negative correlation with optimum water absorption in all flours ( $r = -0.514$ ,  $P < 0.01$ ). Water retention capacity of 16 wheat flours from various classes negatively correlated with optimum water

absorption ( $r = -0.707$ ,  $P < 0.01$ ). Oh et al (1985b) reported that protein quality, damaged starch content, particle size distribution, and pentosan content probably influence the optimum water absorption of noodle dough. Total pentosan content, however, was not correlated with optimum water absorption of noodle dough in this study.

Based on flour characteristics related to optimum water absorption of noodle dough for making white salted noodles, we developed prediction models for the estimation of optimum water absorption of noodle dough for making noodles using multiple linear regression analysis. Regression equations for the prediction of optimum water absorption of noodle dough are:

$$-0.568 \text{ PC} + 41.716 \quad (r^2 = 0.692, P < 0.001) \quad (1)$$

$$-0.701 \text{ PC} + 0.089 \text{ WR} + 37.578 \quad (r^2 = 0.833, P < 0.001) \quad (2)$$

$$-0.865 \text{ PC} + 0.062 \text{ WR} + 0.034 \text{ SD} + 39.606 \quad (r^2 = 0.861, P < 0.001) \quad (3)$$

where PC is protein content, WR is water retention capacity, and SD is SDS sedimentation volume. Protein content of flour plays a more significant role in optimum water absorption for noodle making than any other flour characteristics. Estimation of optimum water absorption of noodle dough was improved consistently ( $r^2 = 0.692$  to 0.833 and 0.861) when water retention capacity and SDS sedimentation volume were incorporated into the equation, in addition to protein content of flour. Estimated optimum water absorption using Equation 3 correlated with the optimum water absorption determined during noodle making at  $P < 0.001$  (Fig. 1). The prediction model (Equation 3) estimated optimum water absorption with a standard error of estimation of 0.535. A prediction equation developed using protein content, water retention capacity and SDS sedimentation volume of flour provides a reliable estimation of the optimum absorption of noodle dough for making noodles.

## CONCLUSIONS

Water absorption of noodle dough significantly influences not only the characteristics of noodle sheets, but also textural properties of cooked noodles. Optimum water absorption of noodle dough is influenced by protein content, SDS sedimentation volume, and physical properties of flour including damaged starch content, NIRS hardness, and particle size of flour. Our prediction model, including protein content, water retention capacity, and SDS sedimentation volume of flour, estimates water absorption of flour for making noodles with a small deviation from the water absorption determined based on handling and sheeting properties of noodle dough. This prediction model could provide a more convenient way of determining optimum water absorption of wheat flour for making noodles than the farinograph or mixograph, or the method based on perceived handling properties of dough by experienced personnel. Improvement of the prediction equation, however, may be required using a wide range of wheat flours before being widely used by laboratories.

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